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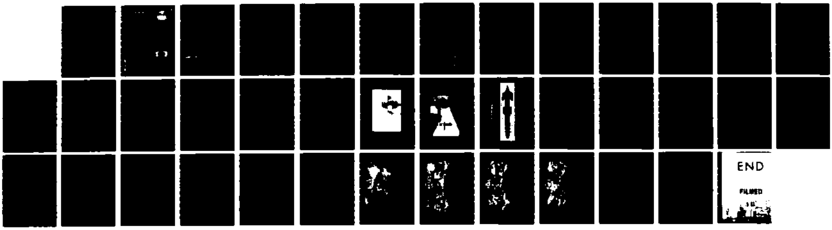

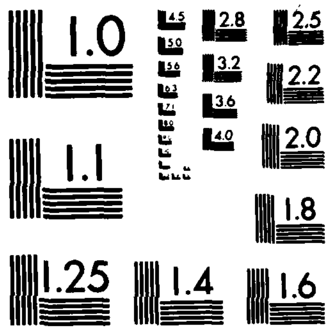

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The United States Air Force (USAF) uses the C-9A aircraft, which is the McDonnell Douglas DC-9, for aeromedical evacuation of patients. Based on results from previous USAF Occupational and Environmental Health Laboratory (USAF OEHL) ozone surveys of the C-141B and C-5A cargo aircraft, Headquarters Military Airlift Command requested an ozone evaluation of the C-9A. Two Columbia Scientific Industries CSI-2000 ozone meters, chemiluminescent devices that are specific for ozone, were used to measure the cabin ozone.

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The Federal Aviation Administration (FAA) has published a standard restricting the cabin ozone levels to no more than 0.250 ppm (sea-level corrected) ceiling concentration and to a 0.1 ppm (sea-level corrected) time-weighted average (TWA) for flight segments greater than three hours. Of concern, are the ozone levels present in the C-9A interior and whether these levels will affect patients with illness or injury that can be synergistic with ozone exposure (i.e., respiratory dysfunctions).

In conjunction with the on-board measurements of ozone, the USAF OEHL collaborated with the National Aeronautical and Space Administration (NASA) and Northwest Orient Airlines. The NASA Nimbus 7 space satellite provided total ozone mapping spectrometer (TOMS) data. TOMS is an ultraviolet monochromator designed to measure the albedo of the sunlit atmosphere from which total ozone in Dobson Units is computed and a spatial distribution mapped. Northwest Orient Airlines (NWA) meteorological staff has developed a very high correlation between the TOMS data and various synoptic meteorolgical features and find that values exceeding 425 suggest an area exceeding the FAA ceiling concentration. As a result, NWA currently uses the synoptic meteorological charts to forecast areas and flight levels of significant ambient ozone levels.

In-flight cabin ozone results were only significant on the first day of measurement, with concentrations as high as 0.344 ppm. On the next three days of flights, the cabin ozone levels were quite low, less than 0.1 ppm. Both the NASA TOMS data and NWA synoptic meteorological charts indicated only significant ambient ozone levels on the first flight day and in the region that the significant cabin ozone levels were found.

In closing, forecasts based on TOMS maps and the synoptic meteorological features could be implemented to provide a pre-flight notification to the flight crew of a potential ozone exposure to themselves and the passengers. The ozone forecast under development can provide information on which flight levels that high ambient ozone levels will be encountered. The pilot can decide whether to fly below the ozone or around any isolated pockets. As for aeromedical evacuation, the flight crew can refer any significant ozone forecast to the medical crew for a decision on deferring the aeromedical evacuation of a patient or use of supplemental breathing oxygen.

Report No. 82-5

USAF OCCUPATIONAL AND ENVIRONMENTAL

HEALTH LABORATORY

Brooks AFB, Texas 78235

OZONE SURVEY OF C-9A

JULY 1982

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I. INTRODUCTION

Previous ozone surveys of the C-141 and C-5 aircraft were completed and reported in the USAF OEHL Technical Report 81-37 in August 1981 (1). After the review of this document, Lt Colonel Dean Nelson of HQ MAC/SGPE, requested in a 22 Dec 81 letter, ozone surveys of the C-9A aircraft. The Military Airlift Command currently has 18 C-9A aircraft in their inventory. This aircraft is solely dedicated to aeromedical evacuation of patients.

Of concern are the ozone levels present in the aircraft interior and whether these levels will affect patients with illness or injury that can be synergistic with ozone exposures (i.e., respiratory function).

II. LITERATURE REVIEW

Experimental human and animal exposure to ozone has been conducted and revealed the following:

A. Biologically, man shows no effect at the 0.25 parts per million by volume (ppmv) level. After a two-hour exposure in the 0.37 to 0.5 ppmv range there is decreased red blood cell acetylcholinesterase and increased osmotic fragility (2).

B. Symptoms noticeable by normal people are likely to occur at levels between 0.30 and 0.50 ppmv (600-1000 $\mu g/m^3$) (3).

C. Some people, known as reactors, are more responsive to ozone than the normal population. Reactors are found among people with asthma and allergies. Insufficient data are available to determine the lowest ozone levels at which the reactors respond (3).

D. Visual effects have been demonstrated by one set of experiments (4), which indicated a deterioration of night vision. Similar experiments (5) indicated that ozone at 0.3 ppmv for three hours was a mild eye irritant causing visual interferences for some individuals including degradation of dark adaptation.

E. Experimentally, in animals, tolerance to inhalation of lethal doses of ozone occurs as a result of pulmonary edema (6). It is not known whether humans develop tolerance to ozone (3). Smokers are probably less susceptible to ozone than nonsmokers (3).

F. Long-term adverse health effects of low-level ozone exposure are thought to be based on an acceleration of the aging process(es) (6).

G. It is believed that the severity of the response to ozone in repeatedly exposed animals is more dependent on concentration than on duration of exposure (6). In humans, the forced expiratory volume (FEV) and flow reduction responses to ozone were cumulative for the first four hours of exposure followed by adaption or plateau effect (7).

H. There was evidence that free radical scavengers mitigate ozone effects and it has been suggested that vitamin E would provide a protective effect (3). Human experimentation, however, has not substantiated this (8).

I. The primary acute effect of ozone is pulmonary edema (9). The chronic effects (6) are threefold:

1. changes in morphology and function of the lung
2. lung-tumor acceleration
3. aging

The primary reason for concern over low-level, long-term, repetitious exposure is prevention of chronic effects. While no human deaths are reported (2), it is unlikely that chronic effects would be recognized and reported properly.

J. Female subjects show similar pulmonary effects as males, but they are more susceptible at lower levels of exercise. The complaints of "ozone sickness" from flight crews have been fewer than from flight attendants. This may be due to the fact that most flight crews are males with sedentary duties. In contrast, flight attendants are generally females and are physically active in flight (5).

K. Ozone minimum odor detection threshold level lies between 0.02 and 0.05 ppmv (10). However, in our experience much higher levels were required (0.25 ppmv).

L. The Federal Aviation Administration (FAA) has issued a standard on airplane cabin ozone contamination (11). The standard applies to flights of three or more hours in the operation of large transport category airplanes by air carriers and commercial operators. The time-weighted average (TWA) FAA ozone standard for such flights is 0.1 ppmv, sea-level equivalent (760 mm Hg and 25°C). The FAA standard noted that all exercising subjects showed some effects on the respiratory system at 0.3 ppmv, sea-level equivalent ozone. These effects included coughing and restriction of air flow in the bronchioles. As of 20 Feb 80, the ozone permissible ceiling concentration at any point in flight was lowered from 0.30 to 0.25 ppmv, sea-level equivalent.

III. EXPERIMENTAL METHODS

Ozone levels aboard the C-9A were measured using two Columbia Scientific Industries (CSI) CSI-2000 ozone meters. The measurement principle of the instrument is based on the gas-phase chemiluminescent reaction of ozone with ethylene. Figure 1 shows a schematic of the unit. Ambient air is passed through a Teflon[R] filter and a capillary flow control. It reacts with ethylene (C_2H_4) in a chamber with a photomultiplier (PM) tube. The intensity of the generated light, which is detected by the PM tube, is directly proportional to the ozone concentration. The resulting electronic signal is displayed on a meter and an output voltage is provided to drive a strip-chart recorder.

The ethylene gas was stored in an externally mounted lecture bottle (0.016 cu ft), which had a maximum pressure of 1250 psi. The gas was delivered to the 2 ozone meter through a pressure regulator at 30-50 psi and 5-7 cc/min flow. Although not used, the CSI-2000 has a 150 cc internal ethylene storage tank. Both containers, the lecture bottle and the internal storage tank, meet the Department of Transportation (DOT) specification (DOT 3E 1800 [49 CFR 178.42], Seamless Steel Cylinders) for storage of ethylene gas. In accordance with AFR 71-4, Table 9-1, the DOT 3E 1800 type cylinder is approved for transportation of ethylene aboard MAC aircraft with no mission restriction. The entire monitoring unit (ozone meter, chart recorder and lecture bottle of ethylene) was contained in a steel case which weighed 43 lbs and was about 1.2 cu ft in size (6 1/2" W x 17" D x 19" H). The ozone meter and chart recorder were powered by an external 12 volt DC sealed gel-cell type battery. This eliminated any need for an electrical source on the aircraft.

IV. SIMULATED-ALTITUDE CALIBRATION

Previous studies by Cook and Bourke (12) on two types of ozone monitors (ultraviolet-absorbing and gas-phase chemiluminescent ozone monitors) indicated that a correction factor is necessary for proper operation of the ozone monitor at altitude. Ideal gas law corrections will not suffice. The C-9A aircraft use a pressurized system to an equivalent cabin altitude of 8,000 to 10,000 ft. Therefore, the CSI-2000 ozone meter must be calibrated at simulated altitude prior to airborne surveys.

Attachment 1 outlines the simulated-altitude calibration procedures completed in the laboratory prior to any flight surveys. The CSI-1000 ozone generator was calibrated, in compliance with the EPA standard method (13), using a CSI-3000 UV photocal ozone calibrator at the CSI factory in Austin TX. The calibrated ozone generator was connected to the CSI-2000 ozone meter for simulated-altitude calibration in the laboratory, as shown in Figure 2. The CSI-1000 ozone generator was operated at ambient pressure. Prior to entry into the CSI-2000 ozone meter, the ozonated air was reduced in pressure. In addition, the exhaust side of the CSI-2000 was maintained at the same decreased pressure by a vacuum source and pressure regulator. As a result of the two pressure regulators being maintained at the same decreased pressure, the reaction chamber and all air-flow lines within the CSI-2000 were kept at the same constant pressure.

V. AIRBORNE SURVEY PROCEDURE

The CSI-3000 was set up at the USAF OEHL and operated 24 hours before final calibration check of the CSI-2000. This allowed sufficient time to condition the CSI-3000 to achieve a stable ozone output. The two CSI-2000 ozone meters were calibrated and shipped to Scott AFB IL.

A. The measurement protocol for the airborne surveys is outlined in Attachment 2. Only the CSI-2000 and battery packs were mounted on the aircraft. One six-foot long (1/4 inch diameter) Teflon^R sampling line sampled the breathing zone air of the aircraft commander (see Figure 3). It is realized that because the sample line was mounted on the pilot's seat it represented an area sample. However, on most flights the pilot rarely left his seat and this protocol approximated a breathing zone sample. This prevented any interference to the pilot during operation of the aircraft.

B. The second CSI-2000 ozone meter was set adjacent to a litter stand in the breathing zone of a litter patient measured. Figure 4 is an actual photograph of the sampling location. Figure 5 is a diagram illustrating a typically configured C-9A aircraft with three litter stands set up. Each litter stand can hold up to four litter patients, but normally only two patients are placed in a single litter stand.

VI. RESULTS AND DISCUSSION

Altitude Correction Factor Calibration

The altitude correction factor calibration results are reported in Attachment 3. Experimentally determined correction factors did not follow the ideal gas-law pressure relationship. The last two columns of Attachment 3 provide a comparison of the empirically determined correction factor and the ideal gas-law pressure ratio. For cabin pressures of 12.82 to 11.34 pounds per square inch, absolute (psia), the correction factors were 1.60 to 2.03 instead of the 1.15 to 1.30 expected from an ideal gas-law pressure ratio calibration (12).

C-9A Measurements

As seen in Attachment 4, four separate flight dates were measured, 28 Apr 82, 30 Apr 82, 1 May 82 and 2 May 82. Although the C-9A can fly up to 4.5 hours, a normal flight leg is about an hour. After either a 20 min ground time or 50 min (if fueling operations are required) the aircraft begins its next flight leg. Aircrews are restricted to a 15-hour flight day. This time starts when the aircraft leaves the originating base or airport and ends when the aircraft is chocked at the rest over night (RON) location. Aircrews are then given a minimum of 12 hours rest prior to the next flight. A typical C-9A mission includes six or seven stops per day for a total of two or three days. Aircrews generally fly 60-90 hours per month and must have 120 hours per quarter to maintain flying status. As seen from the flight times, only one flight leg exceeded three hours where the FAA TWA standard could be applied. This was on the 2 May 82 flight from Travis AFB to Kelly AFB (3 hrs 15 min). Neither the pilot (0.064 ppm) or litter stand patient (0.082 ppm) exceeded the 0.1 TWA standard.

As for the FAA 0.250 ppm ceiling concentration limit, it was exceeded only once. This was on the 28 Apr 82 flight leg from McChord AFB, near Seattle WA, to Travis AFB CA. The levels were as high as 0.344 ppm on the litter stand patient and 0.330 ppm at the pilot's breathing zone. No biological response was noted on any patient passengers or aircrew members.

Meteorological Forecasting

In 1981, Northwest Airlines (NWA), NASA Goddard Space Flight Center, and the FAA conducted a joint study which evaluated the Total Ozone Mapping Spectrometer (TOMS) data obtained from the Nimbus 7 satellite. The TOMS instrument is an ultraviolet monochromator designed to measure the albedo of the sunlit atmosphere from which total ozone can be computed and the spatial distribution mapped. Units mapped are called Dobson Units and a value of 425 or greater indicates an area of ozone exceeding the FAA ceiling concentration.

Mr Dan Sowa (NWA) and Dr Arlin Krueger (NASA) have found a very high correlation between the TOMS data and various synoptic meteorological features. As a result of this study, NWA can use either the TOMS data or synoptic meteorological charts to forecast areas and flight levels of significant ozone concentrations. These ozone forecasts are routinely provided to NWA flight crews as part of the pre-flight meteorological briefing.

Mr Dan Sowa (NWA), in a mutual exchange of scientific information, provided daily ozone forecasts to the USAF OEHL during the C-9A survey. High ozone levels at altitudes below 37,000 ft, which is the operational ceiling of the C-9A, require special meteorological conditions. The NWA Meteorological Center was used to verify the locations and flight levels of significant ozone concentrations. The only day that significant ozone was forecast at the C-9A flight levels was on 28 April 82. There was no significant ozone forecast for the flight levels and routes on 30 April, 1 and 2 May 82. As can be seen from the data in Attachment 4, there were in-cabin ozone readings above the FAA ceiling concentration during the McChord AFB to Travis AFB flight on 28 April 82. No ozone levels above the ceiling concentration were recorded on 30 April, 1 and 2 May. These data correlate with the NWA ozone forecasts.

Ambient Ozone Levels

Dr Arlin Krueger, of the Stratospheric Physics and Chemistry Branch, NASA Goddard Space Flight Center, provided the USAF OEHL with TOMS maps covering the United States during the period of the USAF OEHL C-9A survey. The only significant ambient ozone levels were located between Scott AFB and Denver and between McChord AFB and Travis AFB on 28 April 82 (Atch 5). The TOMS data, as well as the NWA ozone forecasts, show excellent agreement with the in-cabin ozone observed during the C-9A flights and the ambient ozone levels reported in Atch 5. Other potential applications of the TOMS data are described in Atch 6.

VII. RECOMMENDATIONS AND CONCLUSIONS

A. Significant levels of ambient ozone at the flight altitudes that the C-9A flies are present when unique meterological conditions occur. These conditions force the elevated ambient ozone from the stratosphere to the cruise altitude of the C-9A (37,00 ft or less). Most flight legs of the C-9A are less than an hour, requiring approximately 20 minutes for the aircraft to ascend to the cruise altitude and 20 minutes to descend from the cruise altitude. Thus, on flight legs of less than an hour, no more than 20 minutes is spent at cruise altitude. Elevated ambient ozone levels at the C-9A cruise altitude occur about once a week. Thus, it is readily seen that only infrequently will a C-9A aircraft fly through elevated ambient ozone that could impact on aeromedical patient transport.

B. Since the findings of this report demonstrated ozone ceiling concentration measurements in excess of the FAA ceiling concentration standard of 0.250 ppm, further action is warranted. The FAA established this standard following human subject experiments in an altitude chamber. These volunteers were healthy males and females. The 0.250 ppm ozone ceiling concentration standard was established to protect healthy people against any biological effects due to ozone exposure. No safety factor was incorporated in the standard. No literature is known on the health impact of acute exposure of ozone to aeromedical patients or what levels are considered safe for their transport.

C. Four alternatives are possible for corrective action and are as follows:

1. Implement the synoptic meterological ozone prediction capability such as the one used by Northwest Orient Airlines. Air Weather Service could report elevated ambient ozone levels to the pilot, who could in turn notify the medical crew director. The medical crew director could consult with a flight surgeon on whether a particular patient should be exposed to elevated ozone levels on the particular aeromedical evacuation flight or deferred transport. The ozone prediction capability will provide information on the altitude at which the ozone levels are encountered. The pilot can decide whether to fly below the ozone. A second option is to have oxygen available during the flight. The use of oxygen on the patients could be implemented if the medical crew notes the typical biological responses of ozone exposures. These responses were reported earlier in this technical report.

2. Implement the TOMS into the Air Weather Service system. This will not only provide an ozone prediction capability, but would enhance flight operations, flight safety and improve other meterological predictions (see Atch 6). These enhanced meterological predictions would benefit all U.S. Air Force flying operations.

3. Install catalytic converters on the C-9A aircraft to degrade the ambient ozone. This technology is state of the art. The catalytic converter would remove at least 83% of the ambient ozone. After initial installation, the unit would not require maintenance. The device is currently installed on all commercial DC-10, B-747 and L-1011 aircraft with no reported problems. Each unit would weigh less than 18 pounds and cost between $5,000 to $9,000. Currently, the Air Force has 18 C-9A aircraft in use as aeromedical transports. Two units would be required for each aircraft and replacement would be necessary every three years.

4. Do nothing, other than instruct medical crews on the symptoms of ozone exposure and develop procedures for use of oxygen on aeromedical patients.

D. The USAF OEHL recommends option 1 or 2. The ozone prediction capability provided by either option 1 or 2 could be used not only for the C-9A but for other MAC aircraft. A previous USAF OEHL Technical Report 81-37 demonstrates elevated in-cabin ozone levels on the C-5A aircraft. The ozone prediction capability would provide C-5A crews information on whether to use supplemental oxygen or risk exposures to C-5A passengers.

In closing, no engine modification or installation of catalytic ozone converters is recommended. Only infrequent and intermittent ozone levels will be encountered that could be readily forecasted. Thus, operational planning can handle these known appreciable ozone levels if the ozone prediction service is implemented.

FIGURES

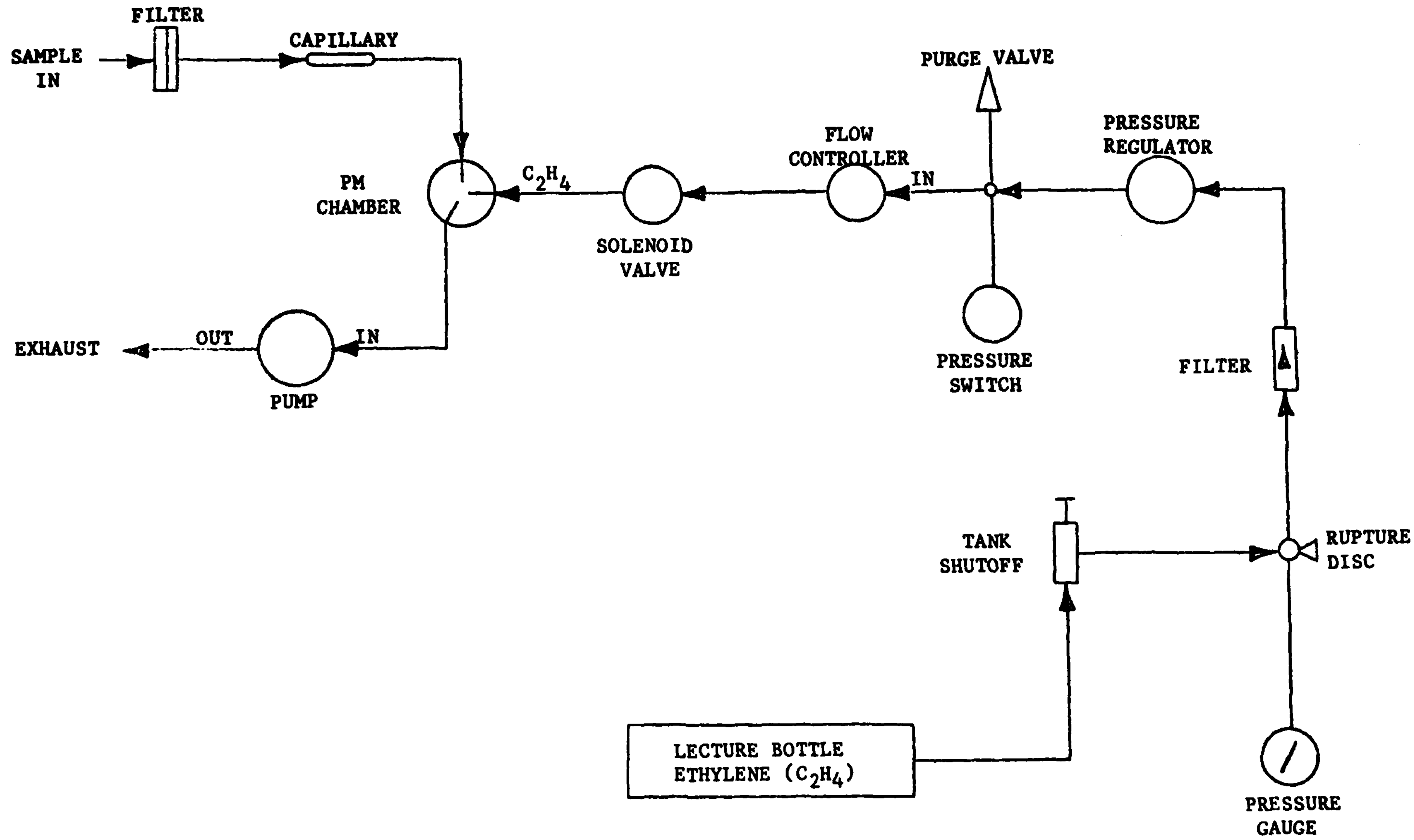

FIGURE 1 CSI 2000 FLOW DIAGRAM

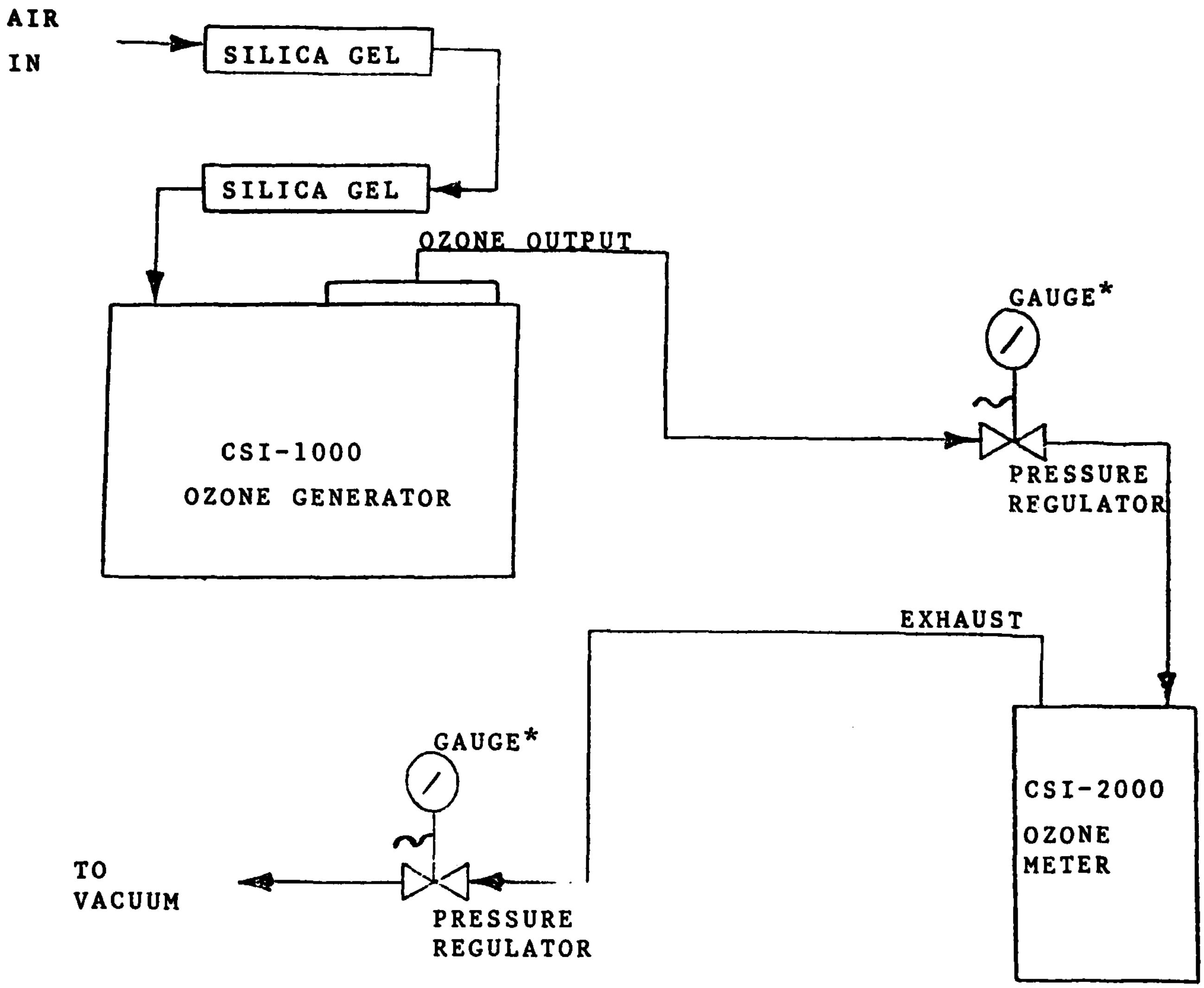

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FIGURE 2 SIMULATED ALTITUDE OZONE CALIBRATION

Figure 3. C-9A Pilot Sampling Position

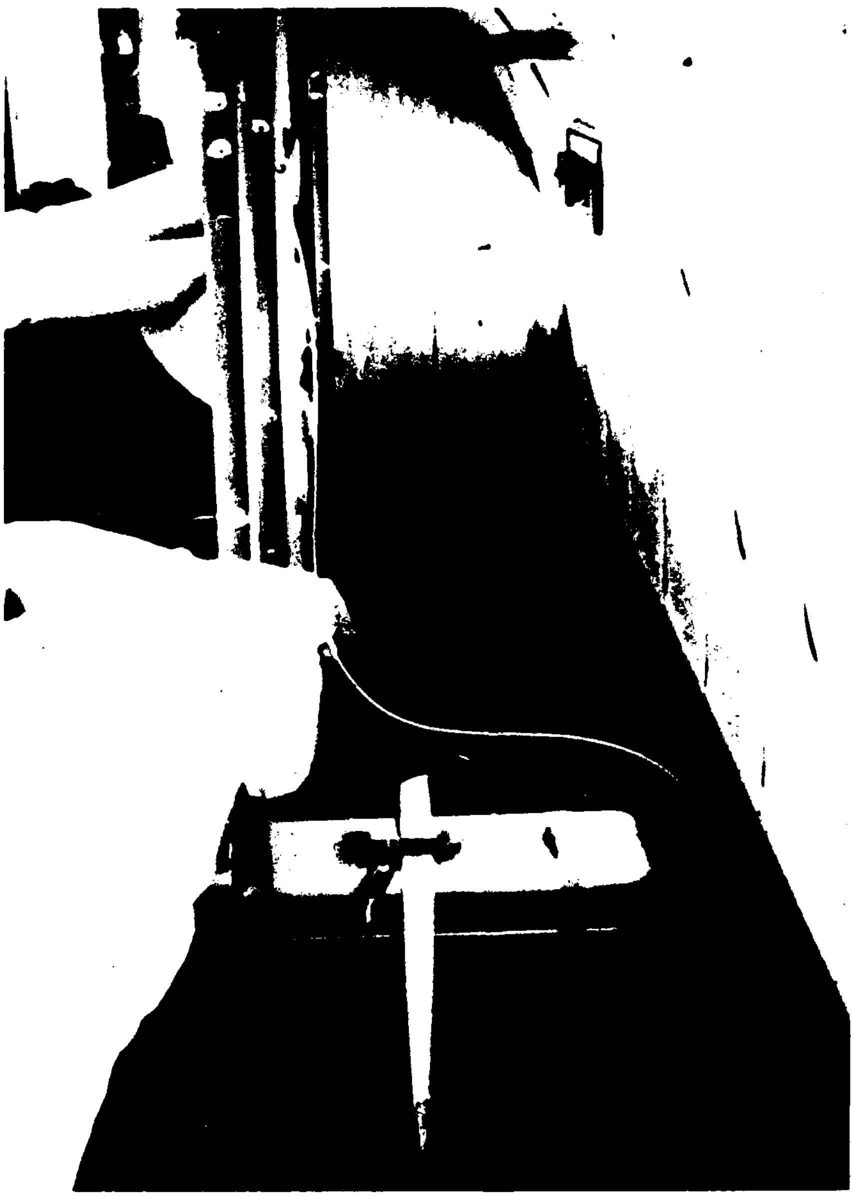

Figure 4. Litter Stand Sampling Position

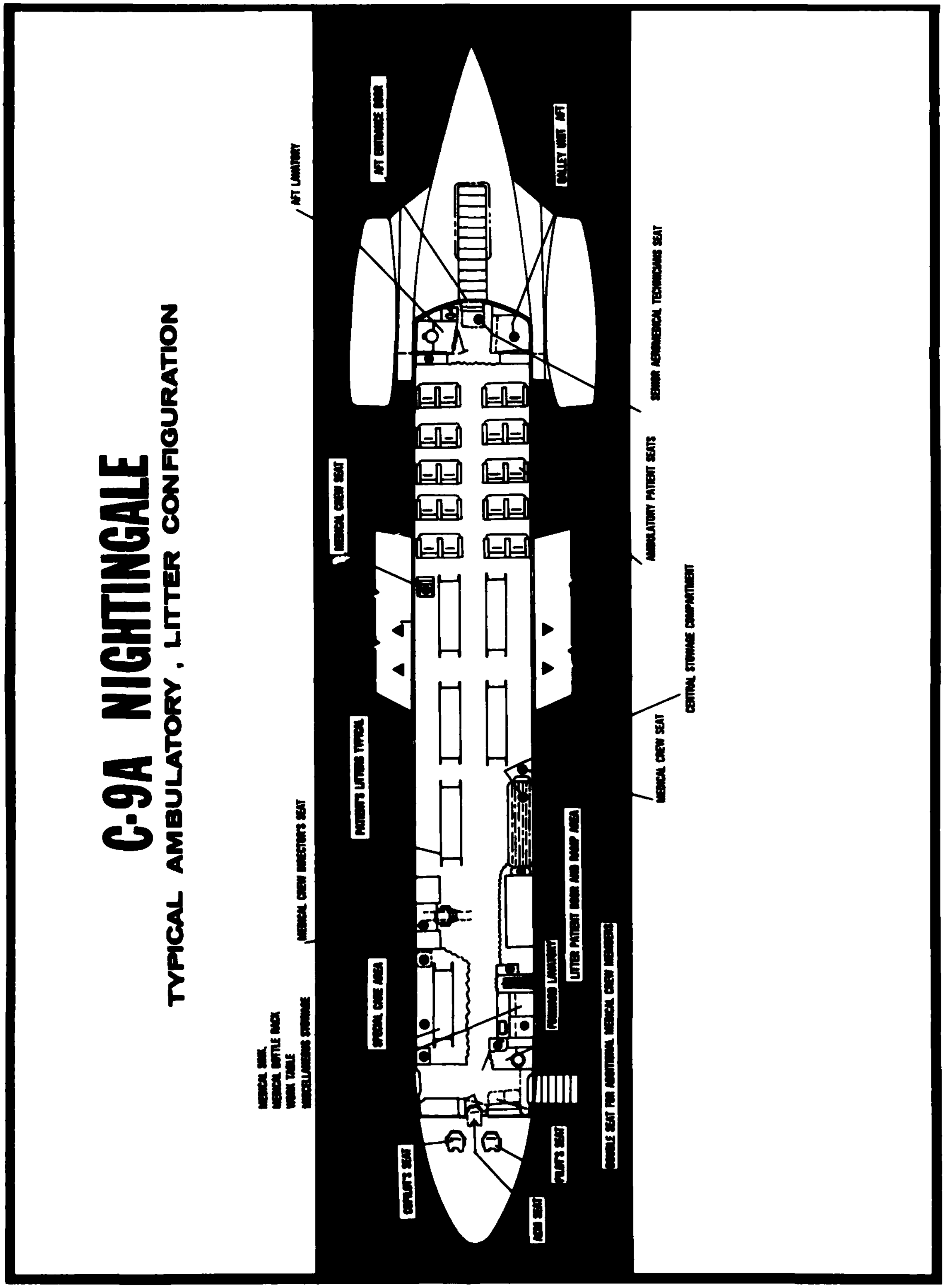

Figure 5. Normal C-9A Configuration of Litter Stands

ATTACHMENTS

ATTACHMENT 1

Simulated-Altitude Calibration Procedure

1. Setup CSI-1000 and CSI-2000 with the two pressure gauges and controllers as specified in Figure 2.

2. Allow the CSI-1000 to run a minimum of four hours prior to any calibration to condition the reaction chamber of the ozone generator (Initially set at an output of approximately 100 ppb).

3. On the CSI-2000, verify the zero and span positions, set to sample mode and allow at least a half-hour prior to verification of any readings on the unit.

4. Use the factory calibration curve for the CSI-1000 to determine the actual ozone output.

5. The actual ozone output on the day of calibration must be temperature and pressure corrected as follows:

$$C_2 = C_1 \frac{T_1}{T_2} \quad \frac{P_1}{P_2} = C_1 \quad \frac{(75^\circ + 460^\circ F)}{(T_2 + 460^\circ F)} \quad \frac{P_2}{0.983 \text{ atm}}$$

Where:

C_2 = Actual ozone output, (ppb) during calibration

T_2, P_2 = Temp (°F) and pressure (atm) during calibration

T_1, P_1 = Temp (°F) and pressure (atm) during factory calibration (75°F and 0.983 atm)

C_1 = Ozone output (ppb) during factory calibration

6. Adjust CSI-2000 meter to actual concentration (C_2) reading.

7. Adjust pressure on both pressure gauges, let stand five minutes before reading CSI-2000 meter response, and change to next pressure.

8. Complete readings at the folowing pressures:

   a. ambient pressure
   b. 700 mm Hg
   c. 650 mm Hg
   d. 600 mm Hg
   e. 500 mm Hg

9. Repeat steps 2-7 at an ozone output of approximately 200 ppb.

ATTACHMENT 2

Measurement Protocol

Ozone monitoring began when a stable flight level had been established and continued until the aircraft began descent for landing. During the monitoring period the following cockpit data were recorded at least every 20 minutes or as conditions dictated (such as changes in flight level).

a. ZULU time.

b. Present altitude.

c. Cabin absolute pressure (or cabin altitude).

ATTACHMENT 3

Altitude Correction Factor For CSI-2000 Ozone Meter

I		II	III	IV	
Pressure		CSI-1000 Ozone Output	CSI-2000 Ozone Meter Response	Correction Factor	Ideal Gas Law Pressure Ratio
mmHg	psia	ppb	ppb	(Col II/III)	(Standard Pressure/ Pressure)
760	14.70	117	117	1.00	1.00
700	13.54	117	84	1.39	1.09
650	12.57	117	70	1.67	1.17
600	11.61	117	60	1.95	1.27
550	10.64	117	54	2.17	1.38

Linear regression model is as follows:

Correction Factor = $- 0.29P + 5.32$

Where: P = cabin pressure, psia

$R^2 = 0.995$, $R = 0.997$

ATTACHMENT 4

C-9A Ozone Results

Local Time	Zulu Time	Altitude K, ft	Cabin Temp F	Cabin Pressure mm Hg	Corrected Ozone Conc. Litter Stand ppm (STP)[x]	Corrected Ozone Conc. Pilot BZ ppm (STP)
28 Apr 82 Flight 634						
Scott AFB - Buckley ANG Base, Denver CO						
0730 (CDT)	1230	Abort take off for yaw control failure				
0855	1355	Take-off				
0905	1405	31	65	610	0.048	-----
0930	1430	31	65	600	0.079	0.076
0945	1445	35	70	560	0.091	0.102
1000	1500	35	68	560	0.197	0.208
1015	1515	35	67	565	0.227	0.211
1030	1530	35	65	600	0.226	0.219
1045	1545	Descent	67	620	0.072	-----
Buckley ANG Base, Denver CO - Hill AFB Odgen UT						
1025 (MDT)	1625	Take-off	64	600	0.079	-----
1035	1635	31	67	600	0.049	0.055
1045	1645	31	67	600	0.051	0.059
1100	1700	31	67	600	0.057	0.071
1105	1705	Descent	67	625	0.037	0.054
Hill AFB, Odgen AFB - Malmstrom AFB, Great Falls MT						
1200 (MDT)	1800	4.7	65	610	0.034	-----
1215	1815	20	65	600	0.035	0.051
1230	1830	35	67	565	0.054	0.076
1245	1845	35	67	565	0.065	0.086
1300	1900	Descent	67	670	0.031	-----
Malmstrom AFB, Great Falls MT - Fairchild AFB WA						
1325 (MDT)	1925	Take-off	69	680	-----	-----
1330	1930	8	69	620	0.037	0.051
1345	1945	31	69	600	0.073	0.071
1400	2000	Descent	69	630	0.040	0.070
Fairchild AFB WA - McChord AFB WA						
1400 (PDT)	2100	Take-off				
1410	2110	28	70	620	0.150	0.150
1415	2115	28	70	620	0.194	0.194
1420	2120	Descent	70	620	0.183	0.183

[x] STP refers to standard temperature and pressure (25°C, 1 atm).

Local Time	Zulu Time	Altitude K, ft	Cabin Temp F	Cabin Pressure mm Hg	Ozone Conc. Litter Stand ppm (STP)[x]	Ozone Conc. Pilot BZ ppm (STP)
McChord AFB WA - Travis AFB CA						
1540	2240	Take-off	69	770	-----	-----
1545	2245	13	69	710	0.053	0.060
1600	2300	33	71	580	0.344[xx]	0.330[xx]
1615	2315	33	72	580	0.237	0.255[xx]
1630	2330	33	72	585	0.183	0.183
1640	2340	Descent	72	585	-----	0.213
30 Apr Flight 436						
Travis AFB CA - McChord AFB WA						
0715 (PDT)	1415	Take-off	--	---	-----	-----
0730	1430	30	67	630	0.075	0.045
0745	1445	31	70	600	0.096	0.037
0800	1500	31	70	595	0.106	0.049
0815	1515	31	70	600	0.115	0.039
0820	1520	Descent	--	---	-----	-----
McChord AFB WA - Fairchild AFB WA						
1000 (PDT)	1700	Take-off	72	760	-----	-----
1005	1705	17	72	660	0.034	0.016
1015	1715	25	72	660	0.056	0.154
1025	1725	Descent	72	680	-----	0.016
Fairchild AFB WA - Malmstrom AFB, Great Falls MT						
1105 (PDT)	1805	Take-off	--	---	-----	-----
1115	1815	19	72	600	0.058	0.018
1130	1830	25	72	620	0.084	0.027
1135	1835	Descent	--	---	-----	-----
Malmstrom AFB - Mountain Home AFB ID						
1125 (MDT)	1925	Take-off	--	---	-----	-----
1135	1935	17	74	600	0.078	0.056
1145	1945	28	74	605	0.075	0.020
1200	2000	Descent	74	630	0.082	0.036
Mountain Home AFB ID - Hill AFB UT						
1240 (MDT)	2040	Take-off	--	---	-----	-----
1245	2045	17	74	650	0.042	0.016
1300	2100	25	74	650	0.056	0.032
1320	2120	Landed	--	---	-----	-----

[xx]Exceeded the FAA 0.250 ppm ceiling concentration.

Local Time	Zulu Time	Altitude K, ft	Cabin Temp F	Cabin Pressure mm Hg	Corrected Ozone Conc. Litter Stand ppm (STP)	Corrected Ozone Conc. Pilot BZ ppm (STP)
30 Apr Flight 436 (Cont'd)						
Hill AFB UT - Buckley ANG Base CO						
1340 (MDT)	2140	Take-off	--	---	-----	-----
1350	2150	17	76	600	0.048	0.022
1400	2200	25	76	540	0.068	0.011
1415	2215	37	76	540	0.149	0.102
1425	2225	37	76	540	0.151	0.084
1430	2230	Landed	--	---	-----	-----
1 May 82 Flight 634						
Buckley ANG Base CO - Hill AFB UT						
0905 (MDT)	1500	Take-off	--	---	-----	-----
0920	1520	27	70	600	-----	0.039
0930	1530	31	70	600	0.070	0.037
0950	1550	31	70	600	0.079	0.036
1000	1600	Descent	--	---	-----	-----
1015	1615	Landed	69	640	0.064	-----
1030	1630	4.8	68	640	0.052	-----
Hill AFB UT - Mountain Home AFB ID						
1050 (MDT)	1650	Take-off	70	640	-----	-----
1100	1700	25	71	640	0.086	0.033
1115	1715	26	71	640	0.077	0.035
1120	1720	Descent	71	640	-----	-----
1130	1730	3	68	680	0.048	-----
Mountain Home AFB ID - Malmstrom AFB MT						
1150 (MDT)	1750	Take-off	--	---	------	-----
1155	1755	23	70	580	0.049	0.031
1200	1800	30	70	580	0.066	0.054
1215	1815	33	69	580	0.083	0.062
1220	1820	Descent	69	600	0.059	-----
1240	1840	Landed	69	680	0.042	-----
Malmstrom AFB MT - Whidbey Island NAS WA						
1310 (MDT)	1910	Take-off	68	680	0.015	-----
1325	1925	19	67	600	0.047	0.049
1330	1930	28	67	600	0.059	0.049
1345	1945	31	67	600	0.041	0.041
1400	2000	31	67	600	0.059	0.059
1415	2015	Descent	67	600	0.075	0.044
1430	2030	Landed	69	780	0.019	-----

Local Time	Zulu Time	Altitude K, ft	Cabin Temp F	Cabin Pressure mm Hg	Corrected Ozone Conc. Litter Stand ppm (STP)[x]	Corrected Ozone Conc. Pilot BZ ppm (STP)
1 May 82 Flight 634 (Cont'd)						
Whidbey Island NAS WA - Travis AFB CA						
1400 (PDT)	2100	Take-off				
1410	2110	27	69	610	0.076	0.088
1415	2115	33	67	580	0.052	0.044
1430	2130	33	67	585	0.062	0.045
1445	2145	33	66	580	0.060	0.042
1500	2200	33	66	580	0.050	0.037
1515	2215	Descent	65	580	0.062	0.020
2 May 82 Flight 1416						
Travis AFB - Kelly AFB						
0705 (PDT)	1405	Take-off	--	---	-----	-----
0715	1415	23	68	580	0.025	0.042
0730	1430	33	68	580	0.033	0.071
0745	1445	33	68	580	0.033	0.089
0800	1500	33	68	580	0.052	0.062
0815	1515	33	68	580	0.042	0.054
0830	1530	33	67	580	0.042	0.056
0845	1545	33	67	580	0.069	0.081
0900	1600	33	65	580	0.073	0.083
0915	1615	33	65	575	0.072	0.072
0930	1630	33	65	575	0.043	0.047
0945	1645	33	65	575	0.051	0.048
1000	1700	33	65	575	0.051	0.062
				TWA*	0.082	0.064

*TWA refers to time weighted average.

ATCH 5 TOMS Ambient Ozone Data

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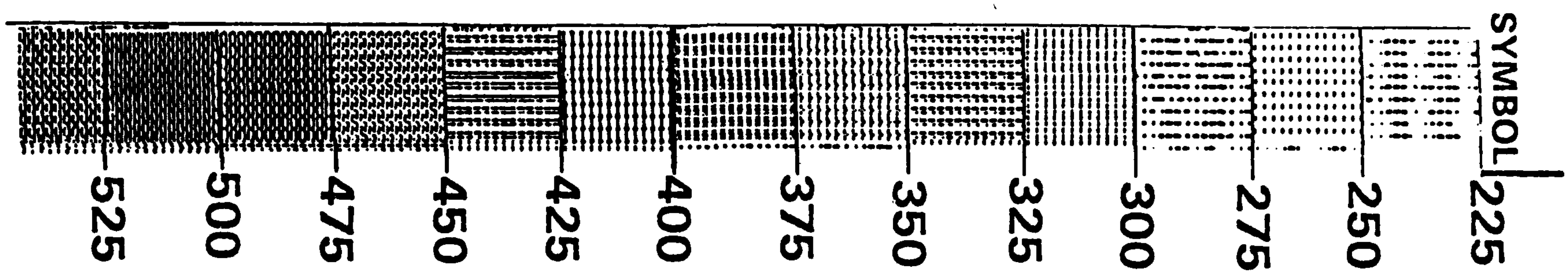
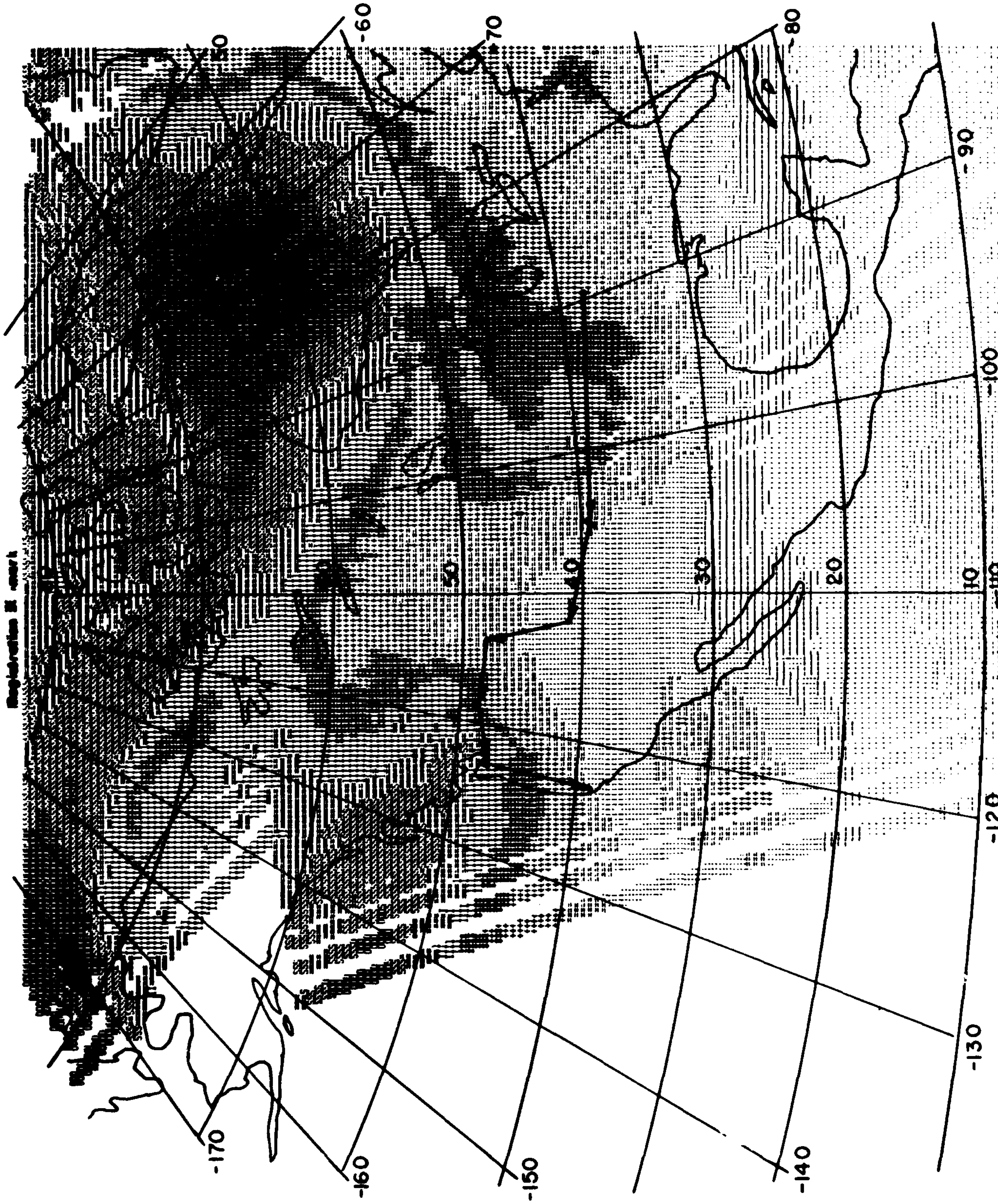
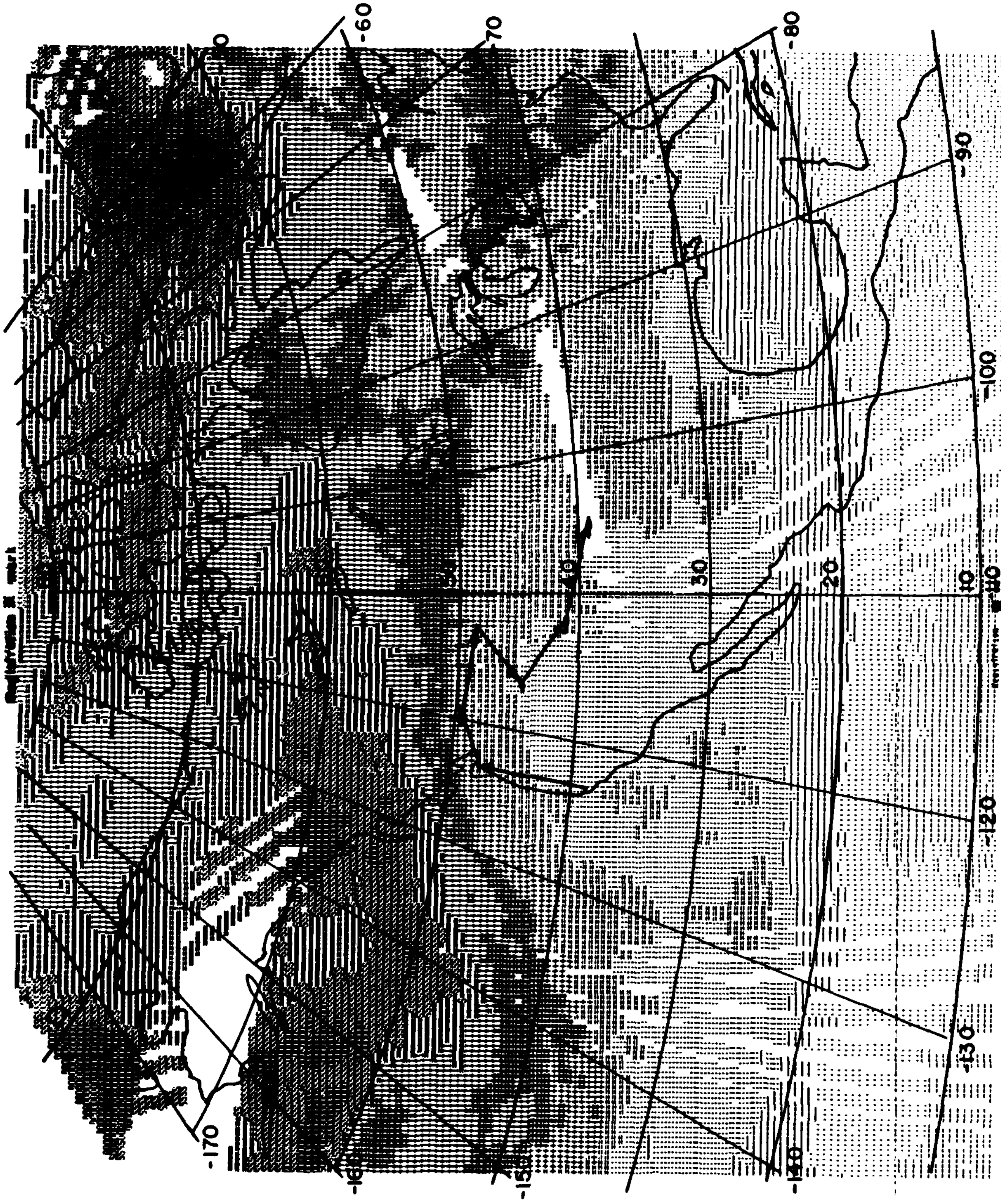
REAL-TIME TOMS GRAY SCALE

TOTAL OZONE, DOBSON UNITS

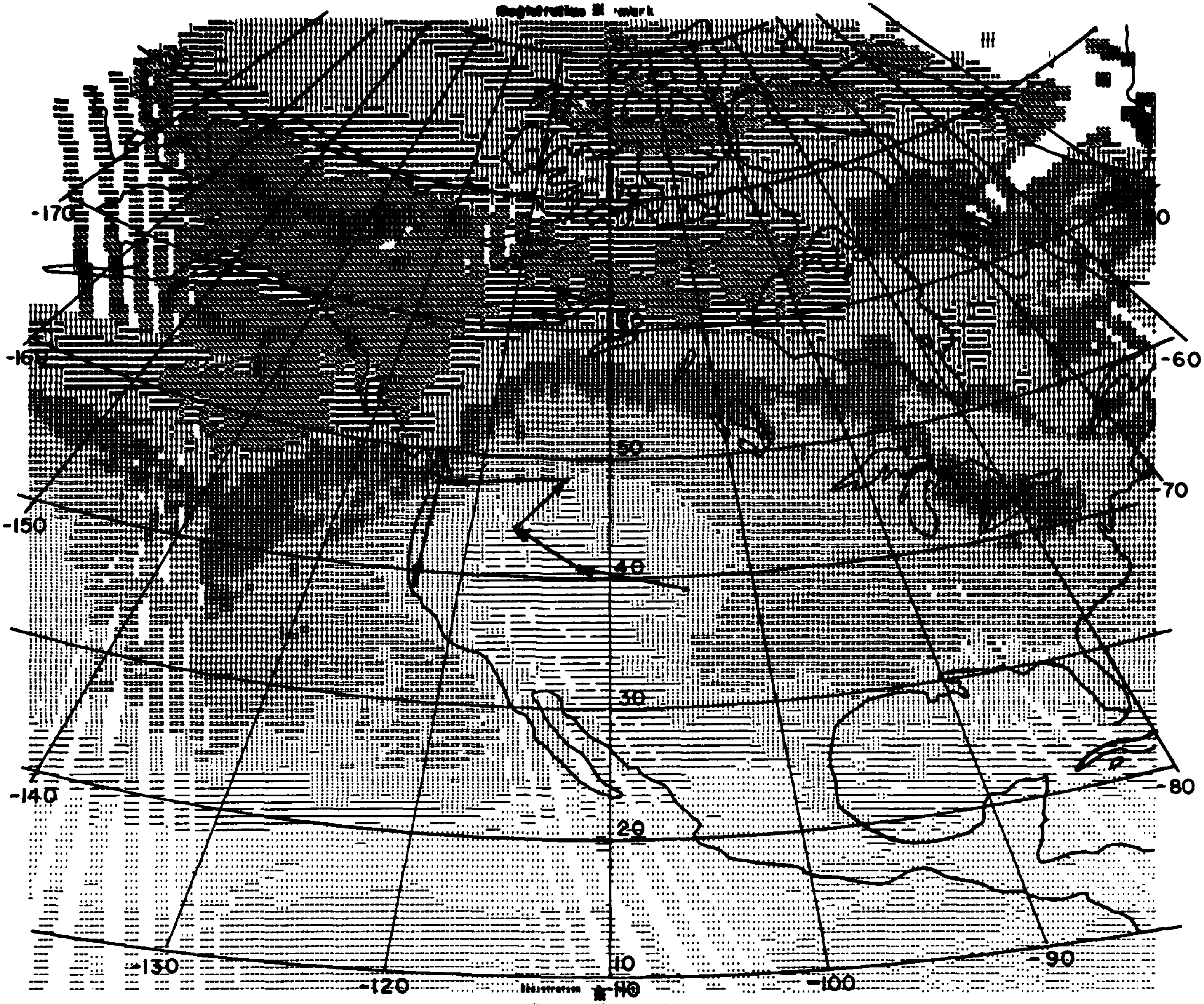




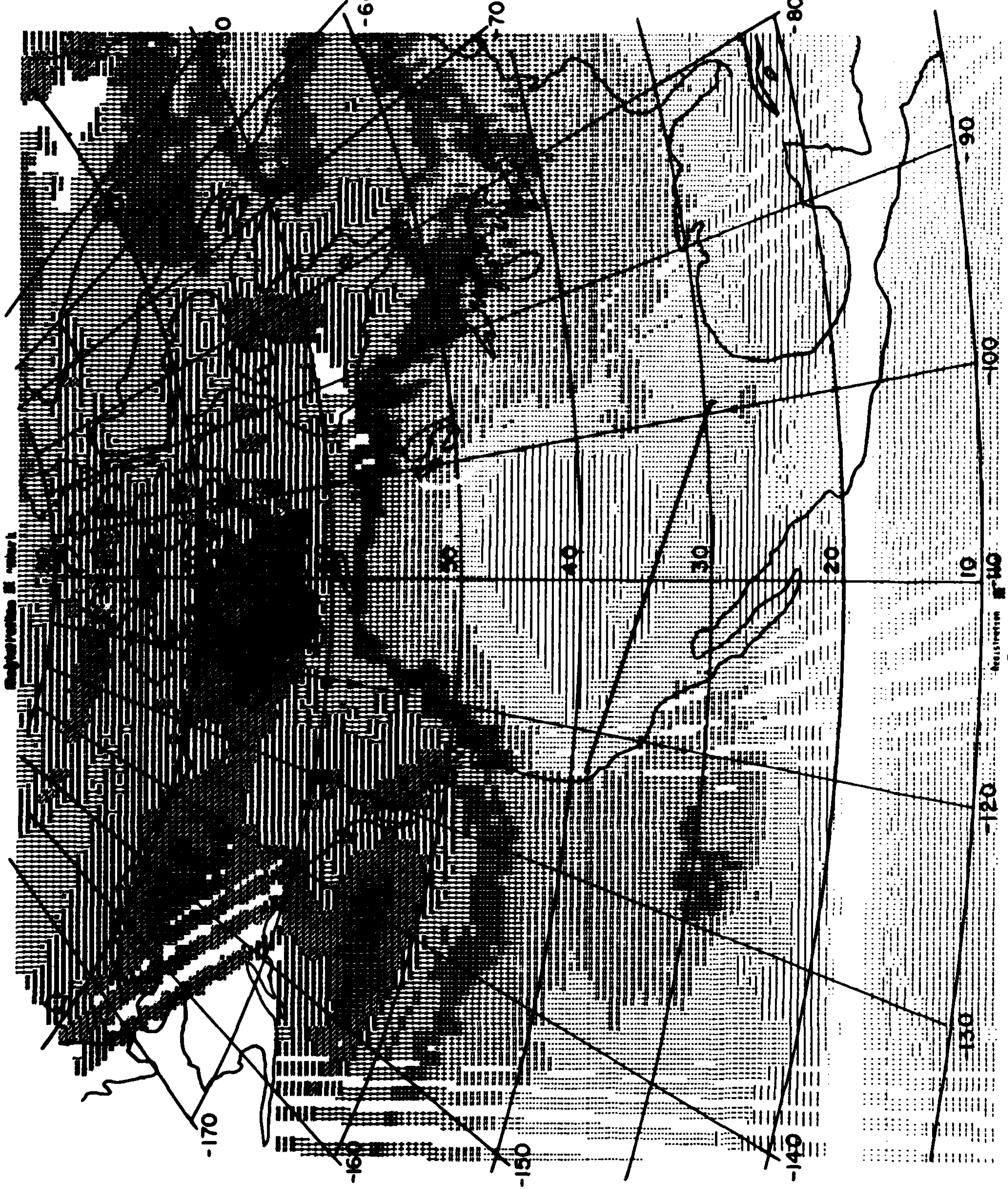
28 APR 1982 - DAY 118



30 APR 1982 - DAY 120



01 MAY 1982 - DAY 121



02 MAY 1982 - DAY 122

ATTACHMENT 6

Other Potential Applications of TOMS Data

The TOMS data appear to have many other potentially beneficial applications for the Air Force. These benefits would be in the areas of flight operations, flight safety and meteorology. The TOMS data appear to be an accurate meteorological instrument that can be used for not only forecasting ozone, but many other important meteorological features including accurate tropopause heights, jet streams, high- and low-pressure systems, ridge and trough lines, short-wave troughs and areas of Clear Air Turbulence (CAT). Potential Air Force benefits include:

Flight Operations. Accurate determinations of tropopause heights and associated jet streams could provide substantial aircraft fuel savings. This could be realized by an aircraft avoiding/utilizing a headwind/tailwind.

Flight Safety. The TOMS data seem to have the capability of accurately forecasting areas of CAT, and more importantly severe CAT. Precision of an order of magnitude or more, over currently used techniques, may be achieved.

Meteorology. Meteorological applications are innumberable. Some of the meteorological parameters and features directly obtainable from TOMS data are listed above. At a minimum, TOMS outputs could supplement AWS atmospheric soundings, surface observations, models and satellite imagery especially in areas where weather data are sparse. It could replace some of these systems. AWS should evaluate the TOMS data for potential Air Force benefits.

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